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Zeolite in Wastewater Decontamination as a Local Development Solution

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Abstract

The contamination of the water basins motivated by the bad handling in the treatment of the residual waters constitutes a present problem for the humanity. If wastewater is discharged directly into rivers, streams, lakes or seas before being properly treated, it is very likely that pollution elements will be introduced that will eventually cause significant ecological damage to the environment and public health diseases (caused by viruses and bacteria) in people and communities that come into contact with these contaminated waters. The work addresses a research that aims to demonstrate the potential of zeolite as a purifying element of wastewater from the Portoviejo river effluents, especially for the removal of ammonium and as a by-product to improve other physical-chemical parameters associated with the water quality, in accordance with the stipulations of Ecuadorian regulations.

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Contents

1. Introduction

The contamination of water sources is a serious problem that humanity faces today. Natural resources are insufficient if current development and consumption policies are continued. This situation has caused collateral effects such as the overexploitation of aquifers, which together with the problems of contamination of water basins, reduces the availability of water to be used in public services and the production of material goods, so it is necessary to take measures to reduce environmental pollution [1].

In the world there is a significant deficit of wastewater treatment; for the year 2002 it was established that 2.6 billion people (42% of the world population) did not have access to an adequate wastewater treatment system, or simply did not have it. The cause of this is the population explosion, the water crisis and the high costs of the facilities to achieve good treatment.

For the year 2015, according to studies carried out by the World Health Organization [2], it is estimated that an extensive use of water is being made worldwide residuals; 10% of the world population consumes food irrigated with wastewater; 20 million hectares in 50 countries are irrigated with raw or partially treated wastewater; the use of gray water growing in developed and developing countries and for Latin America, the figure of 118 294 910 of population without sanitation was established [3].

Polluted waters not only affect the inhabitants of the place but, draining both the streams and the subsoil, pour into the river banks their impurities, expanding the area of pollution and affecting this important source of fresh water [4].

One of the alternatives that can be applied to minimize the problem is the treatment of wastewater with environmental methods that allow water to be reused, recovering the established quality parameters [5].

The treatment of water by the ion exchange process leads to the need to establish the most appropriate operating conditions (pH, type of resin, contact time, etc.) for the removal of the key contaminant.

Currently, the Technical University of Manabí is projected to develop studies aimed at achieving the use of zeolite as a construction material and for the removal of ammonia in wastewater, thereby saving economic resources, while at the same time propitiating the use of a mineral that is available in the coastal region of Ecuador.

2. Research Method

For the characterization of the residual water, both quantitative analysis methods were used, for the precise determination of the chemical composition of the residual water, and qualitative analysis for the knowledge of the physical and biological characteristics. For the determination of the water quality index, the Ecuadorian norm of quality and discharge of effluents was used, contained in Book IV / 2010, of Ecuador [6].

We used five experimental filters built with our own resources, designed to work with four-dimensional particulate zeolite as a filtering material, with the objective of filtering the collected residual water samples.

3. Results and Analysis

In this section, it is explained the results of research and at the same time is given the comprehensive discussion. Results can be presented in figures, graphs, tables and others that make the reader understand easily [2], [5]. The discussion can be made in several sub-chapters.

3.1Wastewater

Wastewater is one whose original characteristics have been modified by human activities and whose quality requires prior treatment, before being reused, discharged into a natural body of water or discharged into the sewerage system [7].

More than the exact chemical knowledge of the composition of the urban wastewater, three are the most important characteristics that should be highlighted, from a sanitary point of view and in relation to the treatment [8]

1. A large amount of solids present.
2. The abundance of biodegradable substances.
3. The presence of a large number of microorganisms

As previously mentioned, a series of substances that can be used as food by the microorganisms present are contained in the wastewater, thus being eliminated from the wastewater, being called biodegradable for this reason.

The nutrition of the microorganisms is done at the expense, not only of the soluble substrates but also of the particulate and insoluble substrates, since these are adsorbed on the bacterial surfaces, where they are attacked by exoenzymes (esterases, carbohydrates, proteases, etc.), decreasing its size to the molecular level. According to its origin, wastewater can be classified as [9]:

a. Domestic: those used for hygienic purposes (bathrooms, kitchens, laundries, etc.). They basically consist of human waste that reaches the sewage networks by means of discharges of hydraulic installations of the building, also in waste originated in commercial, public and similar establishments.
b. Industrial: they are liquids generated in industrial processes. They have specific characteristics, depending on the type of industry.
c. Additional infiltration and flow: the infiltration waters enter the sewer system through the joints of the pipes, walls of the defective pipes, inspection, and cleaning pipes, etc. There is also rainwater, which is discharged by means of several sources, such as channels, drainages and rainwater collectors
d. Stormwater: Is rainwater, which discharges large amounts of water on the ground. Part of this water is drained and another runs off the surface, dragging sand, dirt, leaves and other debris that may be on the ground. The pollution derived from wastewater

Wastewater pollution in the coastal zone should be taken as a historical alarm. Since the Stockholm Agenda had already been, warned about the problem of municipal waters. At the Rio summit (1992) it was said that in 2005 it would be necessary to try to reduce them to 50%, but this has been impossible to achieve [10].

The inadequate management of wastewater can have very serious consequences for human health, the environment, and economic development. Untreated wastewater is a potential polluter of the sources of supply, which increases the risk of infectious diseases, the deterioration of groundwater and other local ecosystems.

The main environmental impacts result in a significant increase in mortality, due to diseases such as cholera, parasitism, among others, that are preventable. Wastewater treatment projects are executed in order to avoid or alleviate the effects of the contaminants they contain. When these projects are executed correctly, their total impact on the environment is positive.

The polluted waters not only affect the inhabitants of the place but, draining both the streams and the subsoil, they dump the contamination on the banks of the rivers, expanding the contaminated area and affecting the freshwater reservoirs [11].

In 2013, the World Health Organization (WHO) stated that approximately 90% of all wastewater in developing countries is discharged directly to rivers, lakes or oceans without treatment; the use of wastewater has increased and shows that 20 million hectares in 50 countries are irrigated with raw or partially treated wastewater; It is thought that 10% of the world's population consumes food irrigated with wastewater, being very difficult to quantify the extent of this situation, due to the informal nature of its practice [6]. When domestic wastewater is released into rivers or bodies of water without any treatment or disinfection, they usually contaminate them with high concentrations of bacteria, viruses, and parasites, creating a serious public health problem. Among the main diseases spread by this poor wastewater management are diarrhea (bacterial and viral), typhoid and paratyphoid, cholera, infectious hepatitis, amoebiasis, giardiasis, among others. As it is very difficult to detect and quantify all pathogens that cause these diseases, sanitary engineers and many public health authorities use fecal coliforms as indicator organisms for pathogen contamination [12].

Most industries produce liquid waste discharges that have very high biochemical oxygen (BOD) demands but lower concentrations of fecal coliforms than domestic wastewater, which can be said to be a major ecological problem and household waste a great public health problem although both contribute to the general deterioration of water quality [12].

The effects of wastewater in the coastal zone depend mainly on the physical conformation of the same. These fixed features of the territory seem to be forgotten when it comes to the management of coastal resources, which is more important when it is estimated that the density of the population of the coastal areas is large, reaching about 80 people per km^2, that is, 2.5 times higher than the total average of the one that inhabits the continents, which indicates the tendency that man has shown to move to these areas due to the advantages that the richness of his resources represents [12].

All the human activities that take place on the coast and especially those that involve wastewater management, depend on the discharge of their waste, on the one hand, from the position they occupy within a watershed, and on the other, the marine currents where they are discharged, this is what at a given moment will define the dilution of them and the mitigation of their effects.

In Ecuador, in 2015, only 52% of the wastewater was treated, occupying the 15th place in the Central and South America region [2].

Pollution of the waters of the Portoviejo River is a problem that directly threatens the health of people residing on the banks of the river. The authorities of the Provincial Government of the Province of Manabí have dedicated enormous efforts to correct the problems of ammonia contamination that presents the waters of the Portoviejo river, being very expensive the use of artificial resins, for what the use of the zeolite as ammoniacal filter wastewater can be a relevant solution to this problem.

In the city of Portoviejo capital of the province of Manabí, wastewater is an inevitable product of human activity. Pollution sources originate in the runoff of cropland affected by the use of fertilizers, as well as industrial and domestic waste. Ammonia is one of the main organic pollutants. As a consequence, measures have been implemented to limit their concentrations in the effluents

3.2 The treatment of wastewater

The treatment of residential wastewater should be understood, as a necessity, in order to maintain adequate health and hygiene conditions for the population, to conserve the quality of the water sources and to promote a rational and sustainable use of aquatic resources.

Currently, proper treatment of wastewater is a major concern for society. The discharge of untreated urban wastewater exerts a series of negative effects on the receiving channels, among which it is worth mentioning [13]:

a. The appearance of sludge and floating that not only cause an unpleasant visual impact but, due to the reducing nature of organic matter, can lead to the depletion of dissolved oxygen present in the water and cause the release of bad odors.
b. Depletion of the oxygen content present in the waters. Consumed oxygen available, the anaerobic degradative processes generate unpleasant odors, by releasing gases that are the cause of these odors.
c. Excessive contributions of nutrients, since wastewater contains nutrients that are responsible for the uncontrolled growth of algae and other plants in the receiving channels (eutrophication)
d. Damage to public health. Among the diseases that can spread include typhus, cholera, dysentery and hepatitis A.

The treatment plants will eliminate a high proportion of the pollutants present in the wastewater, discharging purified effluents, which can be assimilated naturally by the receiving channels. Therefore, treatment stations can be considered as an artificial complement to the natural processes that occur in aquatic masses, since their capacity for self-purification has been greatly exceeded.

In general, the treatment of wastewater in conventional treatment plants consists of up to four stages that include chemical, physical and biological processes [14], among which are the following

1. Preliminary treatment: intended for the elimination of easily separable residues and in some cases a pre-aeration process.
2. Primary treatment: comprising sedimentation and sieving processes.
3. Secondary treatment: comprising aerobic and anaerobic and physic-chemical biological processes (flocculation), to reduce most of the BOD.
4. Tertiary or advanced treatment: which is aimed, the final reduction of BOD, heavy metals and/or specific chemical contaminants and the elimination of pathogens and parasites.

But the construction of a treatment plant is expensive and compromises a piece of land that is sometimes not available. On the other hand, the cost of wastewater treatment by conventional methods can be very high and often local governments do not have enough resources to take mitigating measures. Therefore, in the process of choosing the appropriate sanitation technology, effective alternatives must be considered and the correct option chosen for the specific circumstances.

It is true that in recent years the treatment of wastewater has been carried out by centralized methods, applying massive technologies based on large treatment plants, which are economically and environmentally expensive and where localities are limited to playing a passive role in the management.

The idea is to adopt new concepts, methods and technologies to solve the problem of wastewater from the local development scheme, where decentralized parochial autonomous governments can play an active responsibility role through the application of decentralized technologies, the use of resources indigenous peoples and the implementation of a policy of sustainable and friendly development with nature.

3.3 The zeolite to reduce the decontamination of wastewater

Zeolites are a group of non-metallic minerals, whose deposits are limited to no more than twenty countries, including Ecuador. Its use has been gaining space worldwide; but it is still limited to developed countries of the first world such as: USA; Germany; Japan; Italy; and Russia among others, it is currently intended to develop its use in the country, with some applications in animal feed and water purification, especially in the removal of ammonium and the improvement of other physical and chemical parameters of wastewater [15].

In Ecuador, research on zeolite has been ongoing since the 1990s and since 2000, researchers at the Polytechnic School of the Litoral (ESPOL) have carried out studies both on the Polytechnic campus and along the Chongón Colonche mountain range. in cooperation with the University of Louvain in Belgium and the Polytechnic University of Madrid (UPM) [16].

Zeolites are hydrated aluminosilicate minerals with a cage-like structure that houses large areas both externally and internally. They have a structure of negative charge due to the isomorphic substitution of cations in the mineral. Therefore, they have a strong affinity towards cations and only a small affinity towards anions or organic molecules, Clinoptilolite is the most abundant natural zeolite and, therefore, is a very economical material. This zeolite is very efficient for the removal of ammoniacal nitrogen present in wastewater [16].

Zeolites are composed of aluminum, silicon, sodium, hydrogen, and oxygen. The crystalline structure is based on the three directions of the TO4 network in tetrahedral form, with its four oxygens shared with the adjacent tetrahedral. The physical properties provide unique aspects for a wide variety of practical applications [17].

It has been found that, by appropriately adding natural zeolites in their various cationic modifications in the filtration systems, quite remarkable levels of water purification can be achieved and not only the removal of phosphates, sulphates, and chlorides can be achieved; but also, the elimination of heavy metals such as lead, arsenic, nickel, copper, and other pollutants [18].

Its properties include hydration and dehydration, which is a physical phenomenon that varies according to pressure and temperature, as well as its structural framework, with the direct endothermic effect and exothermic rehydration. The importance of this property lies in the fact that it occurs without alterations in the structural framework of the mineral [15]. Another of the most important properties of zeolites, which makes them mandatory in many dehydration processes, is their great thermal stability and the increase of their adsorption capacity with temperature [19].

Under ambient conditions, the central cavity, as well as its channels, filled with water molecules in the form of spheres surrounding the interchangeable cations. If the water it was displaced at the appropriate temperature (depending on the type of zeolite), they will be able to adsorb molecules, whose diameter is lower than the channels and a central cavity, retaining them inside m. An example of this is its selectivity for gases such as CO2, NH3, among others [20].

The zeolites can be shape-selective catalysts, either by the selectivity of the transition state or by the exclusion of competing reagents based on the diameter of the molecule. They have also been used as oxidation catalysts. The reactions take place within the pores of the zeolite, which allows a greater degree of product control. The main industrial applications are petroleum refining, fuel production, and petrochemical industry. Synthetic zeolites are the most important catalysts in petrochemical refineries [21].

Zeolite offers a filtering effect superior to that of sand or carbon filters, resulting in purer water with better productivity and requiring less maintenance. The highly porous structure of zeolites can capture contaminating particles up to 4 microns. Zeolites are negatively charged naturally, so they can adsorb cations, such as heavy metals and ammonia [22].

It is evident that uncontrolled pollution is occurring in rivers, streams, and estuaries by urban, industrial and mining effluents, with natural zeolites being an effective and cheap alternative for the decontamination of these effluents by adsorbing the most common water elements in their structure. Residuals such as ammonia, hydrogen sulfide, heavy metals, among others; besides the retention of certain colonies of microorganisms, harmful to health [23].

3.4 Discussion of the results

Analysis of the residual water before applying the filtrate with zeolite

Considering the above, it has been considered to carry out an experimental evaluation on the use of zeolite as a wastewater purifier, in order to reduce its contamination. The sample consists of five wastewater effluents that pour into the Portoviejo river of the provincial capital city that bears the same name, as shown in the map of figure 1.

Figure 1. Map with the location of the five wastewater effluents studied

For filtering, a tubular system was built and four layers of zeolite with differentiated granulometry, four different grain sizes, were conditioned in order to provide an adequate level of filtration and a short retention time in the system.

The zeolite of the clinoptilolite type was commercially acquired in the company neonates, located in the canton Isidro Ayora of the neighboring province of Guayas and grains were acquired with the following gravimetry: 1.70mm; 2mm; 2.63mm and; 4.75mm A 6 "(inch) tube was used for the filtering device. In figure 2 shows a technical diagram of the filtering system where the gravimetric structure of zeolite is specified.

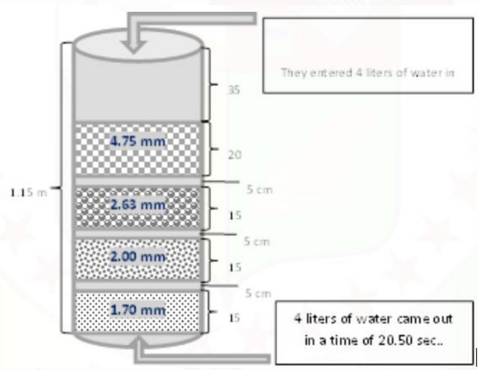

Figure 2. Technical diagram of the filtering system

The results of the laboratory tests before and after the filtration with zeolite allowed verifying the effectiveness of this mineral to improve the parameters of the quality of the wastewater. Among the chemical parameters are the following:

It was possible to remove between 50% and 75% of the total nitrogen and especially the ammoniacal nitrogen of the samples taken. Figure 3 shows a comparative graph with the behavior of the total nitrogen parameter before filtering and after filtering and in figure 4 the same information is shown, but in relation to ammoniacal nitrogen

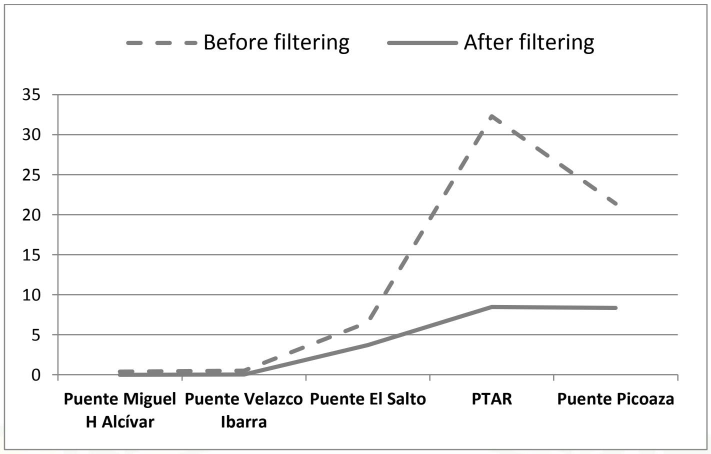

Figure 3. Comparative graph on the behavior of total nitrogen before filtering and after the same

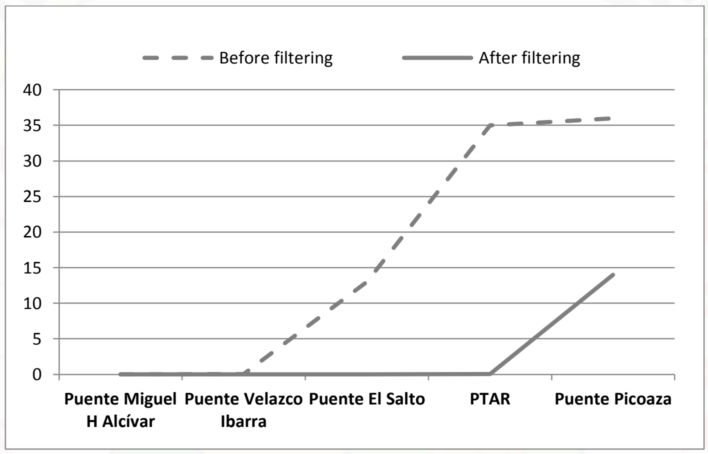

Figure 4. Comparative chart on the behavior of the ammoniacal nitrogen before filtering and after the

It was possible to reduce the phosphate content between 50% and 95%, as well as the biochemical oxygen demand, which can be improved up to 45%. Figure 5 shows the comparative graph of the behavior of the phosphate before filtering and after the same and in figure 6 the same information but the biochemical oxygen demand (BOD) is shown

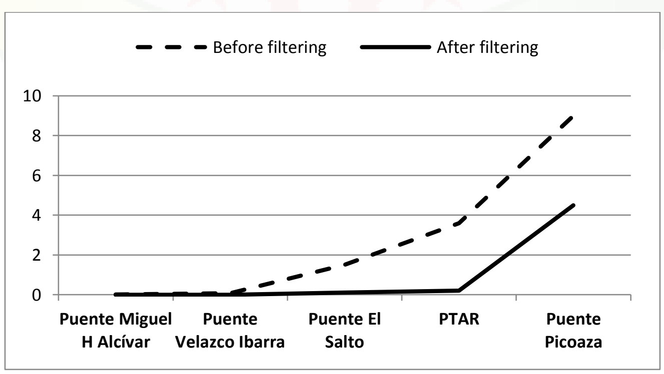

Figure 5. Comparative graph on the behavior of phosphate, before filtering and after the same

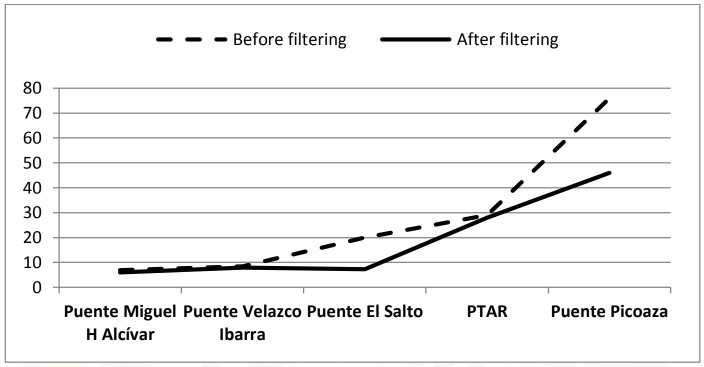

Figure 6. Comparative chart on BOD behavior, before and after filtering

Among the physical parameters that can be improved by filtering with zeolite, are the following

Dissolved solids are reduced by 2% to 8%, as well as suspended solids that can be reduced between 35% and 85%. Figure 7 shows the comparative graph of the behavior of dissolved solids before filtering and after the same and in figure 8 the same information is shown but of the suspended solids.

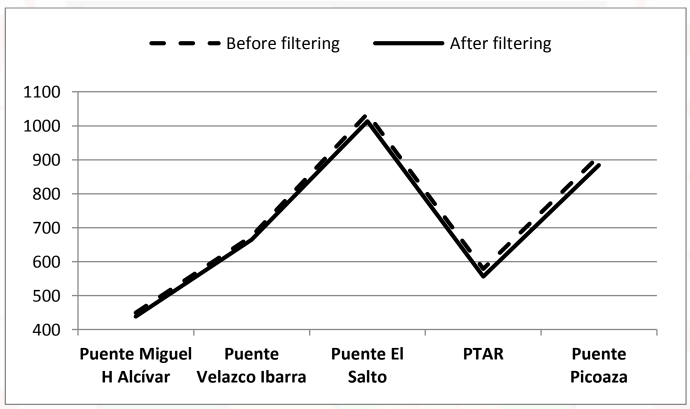

Figure 7. Comparative graph on the behavior of dissolved solids, before and after filtering

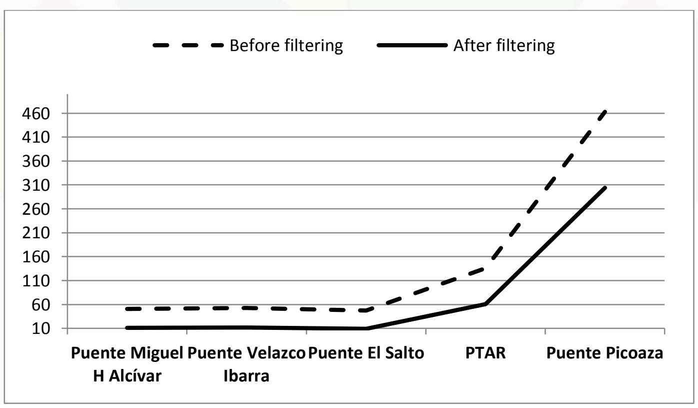

Figure 8. Comparative graph on the behavior of suspended solids, before filtering and after the same

The electrical conductivity was improved up to 3% and the dissolved oxygen was improved between 2% and 7%. In the figure 9 shows the comparative graph on the behavior of the electrical conductivity before filtering and after the same and in figure 10 the same information is shown but related to dissolving oxygen.

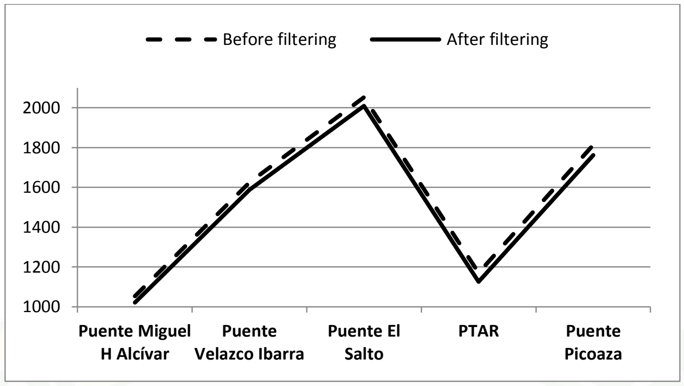

Figure 9. Comparative graph on the behavior of electrical conductivity, before and after filtering

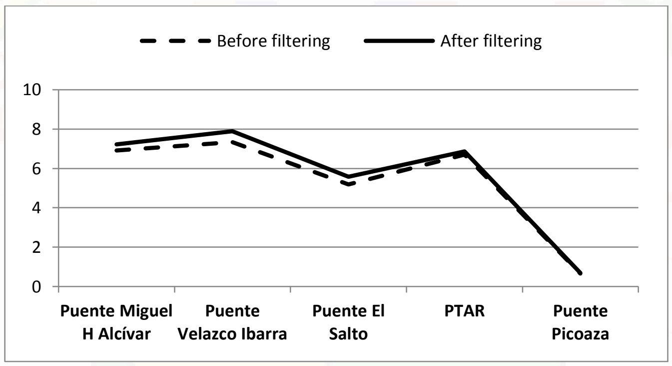

Figure 10. Comparative graph on the behavior of dissolved oxygen, before filtering and after having performed the same

The possibility of being able to use zeolite as a base material for the purification of wastewater from the Portoviejo River effluents demonstrates the potential of being able to apply wastewater treatment solutions within the framework of the local development scheme, using indigenous resources and less costly and environmentally friendly technical methods, which ensures the sustainability of the proposal.

4. Conclusion

The investigation allowed to verify the properties of the zeolite in order to improve the physical-chemical parameters of the wastewater, being able to define in the laboratory analyzes the physical-chemical characterization of the wastewater of five effluents that flow into the Portoviejo river, being able to identify those corresponding to the wastewater treatment plant and the Picoaza bridge, as those most contaminated with ammonium.

The possibility of being able to use zeolite as a base material for the purification of wastewater from the Portoviejo River effluents demonstrates the potential of being able to apply wastewater treatment solutions within the framework of the local development scheme, using indigenous resources and less costly and environmentally friendly technical methods, which ensures the sustainability of the proposal.

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